

WE CLAIM:

1. A circulator device for launching an optical signal into an optical device and for outputting the optical signal after modification by the optical device comprising:
 - an input port for inputting the optical signal;
 - a polarization beam splitter optically coupled to the input port for separating the optical signal into first and second orthogonally polarized sub-beams;
 - a first polarization rotator for rotating the polarization of at least one of the first and second orthogonally polarized sub-beams of the optical signal, so that both sub-beams of the optical signal have the same polarization;
 - polarization beam directing means for directing optical sub-beams with a first polarization along one set of paths, and for directing optical sub-beams with a second polarization along another set of paths;
 - non-reciprocal polarization rotating means for rotating the polarization of optical sub-beams traveling in a first direction therethrough, while having no overall effect on the polarization of optical sub-beams traveling in a second direction therethrough;
 - a first input/output port for outputting the first sub-beam of the optical signal with the first polarization, and for inputting a first sub-beam of the modified optical signal with the first polarization, whereby the first sub-beam of the modified optical signal travels back through the non-reciprocal polarization rotating means and the polarization beam directing means;
 - a second input/output port for outputting the second sub-beam of the optical signal with the first polarization, and for inputting a second sub-beam of the modified optical signal with the first polarization, whereby the second sub-beam of the modified optical signal travels back through the non-reciprocal polarization rotating means and the polarization beam directing means;
 - a second polarization rotator for rotating the polarization of at least one of the first and second sub-beams of the modified optical signal, so that the sub-beams of the optical signal have orthogonal polarizations;
 - a polarization beam combiner optically coupled to the output port for combining first and second orthogonally polarized sub-beams of the modified optical signal; and
 - an output port for outputting the modified optical signal;whereby light entering the first and second input/output ports with the second polarization will be directed away from the input and output ports.
2. The circulator device according to claim 1, wherein the polarization beam directing means comprises a prism with a pair of polarization beam splitting coatings for redirecting the sub-beams

of the optical signal or the sub-beams of the modified optical signal from a first pair of paths to a second pair of paths, which are parallel to the first pair of paths.

3. The circulator device according to claim 2, wherein the polarization beam combiner comprises a birefringent crystal disposed in the first pair of paths; and wherein the polarization beam splitter comprises a birefringent crystal disposed in the second pair of paths.

4. The circulator device according to claim 1, wherein the input port comprises a lens for collimating the optical signal launched from an input fiber; and

wherein the output port comprises a lens for focusing the modified optical signal onto an output fiber.

5. The device according to claim 1, wherein the polarization beam directing means comprises a first birefringent walk-off crystal with a first birefringent axis; and wherein the polarization beam splitter and the polarization beam combiner comprise a second birefringent walk-off crystal with a second birefringent axis, perpendicular to the first birefringent axis.

6. The circulator device according to claim 1, wherein the first polarization rotator means comprises:

a first half wave plate for rotating the polarization of one of the first and second sub-beams of the optical signal by 45° in a first direction;

a second half wave plate for rotating the polarization of the other one of the first and second sub-beams of the optical signal by 45° in a second direction opposite to the first direction; and

a Faraday rotator for rotating the first and second sub-beams of the optical signal by 45° in the first direction when passing in one direction therethrough and by 45° in the second direction when passing in the opposite direction therethrough.

7. The circulator device according to claim 1, wherein each of the first and second non-reciprocal polarization rotator comprises a half wave plate for rotating the polarization of the first and second sub-beams by 45° ; and a Faraday rotator for rotating the polarization of the first and second sub-beams by 45° in a first direction for sub-beams traveling in one direction therethrough and in a second direction, which is opposite to the first direction, for sub-beams traveling in the opposite direction therethrough.

8. A circulator device for launching an optical signal into an optical device for modification and for outputting the modified optical signal comprising:

- a first port for inputting the optical signal;
- a second port adjacent the first port for outputting the modified optical signal;
- a polarization beam splitter/combiner optically coupled to the first port for separating the optical signal into first and second orthogonally polarized sub-beams, and optically coupled to the second port for combining first and second orthogonally polarized sub-beams of the modified optical signal;
- polarization rotator for rotating the polarization of at least one of the first and second orthogonally polarized sub-beams of the optical signal, so that both sub-beams of the optical signal have the same polarization, and for rotating the polarization of at least one of the first and second sub-beams of the modified optical signal so that the sub-beams of the modified optical signal have orthogonal polarizations;
- polarization beam directing means for directing optical sub-beams with a first polarization along one set of paths, and for directing optical sub-beams with a second polarization along another set of paths;
- non-reciprocal polarization rotating means for rotating the polarization of optical sub-beams traveling in a first direction therethrough, while having no overall effect on the polarization of optical sub-beams traveling in a second direction therethrough;
- a third port for outputting the first sub-beam of the optical signal with the first polarization, and for inputting the first sub-beam of the modified optical signal with the first polarization;
- a fourth port for outputting the second sub-beam of the optical signal with the first polarization, and for inputting the second sub-beam of the modified optical signal with the first polarization;

whereby light entering the third and fourth ports with the second polarization will be directed away from the first and second ports.

9. The device according to claim 8, wherein the polarization rotator comprises:

- a first half wave plate for rotating the polarization of one of the first and second sub-beams of the optical signal and one of the first and second sub-beams of the modified optical signal by 45° in a first direction;
- a second half wave plate for rotating the polarization of the other one of the first and second sub-beams of the optical signal and the other one of the first and second sub-beams of the modified optical signal by 45° in a second direction, which is opposite to the first direction, whereby both the first and second sub-beams have the same polarization; and

a Faraday rotator for rotating the first and second sub-beams of the optical signal by 45° in one direction when passing in one direction therethrough and by 45° in the second direction when passing in the opposite direction therethrough.

10. The device according to claim 8, wherein the polarization beam directing means comprises a first birefringent walk-off crystal with a first birefringent axis; and wherein the polarization beam splitter/combiner comprises a second birefringent walk-off crystal with a second birefringent axis, perpendicular to the first birefringent axis.

11. The device according to claim 8, wherein the non-reciprocal polarization rotator comprises a half wave plate for rotating the polarization of the first and second sub-beams by 45° ; and a Faraday rotator for rotating the polarization of the first and second sub-beams by 45° in a first direction for sub-beams traveling in one direction therethrough and in a second direction, which is opposite to the first direction, for sub-beams traveling in the opposite direction therethrough.

12. A circulator comprising:
a first port for inputting an input optical beam;
a second port adjacent the first port for outputting a output optical beam;
a polarization beam splitter/combiner for separating the input optical beam into orthogonally polarized sub-beams, and for combining orthogonally polarized sub-beams of the output optical beam;
polarization rotating means for rotating the polarization of at least one of the orthogonally polarized sub-beams of the input optical beam, so that both sub-beams of the input optical beam have the same polarization, and for rotating the polarization of at least one of the sub-beams of the output optical beam so that the sub-beams of the output optical beam have orthogonal polarizations;
polarization beam directing means for directing optical sub-beams with a first polarization along one set of paths, and for directing optical sub-beams with a second polarization along another set of paths;
non-reciprocal polarization rotating means for rotating the polarization of optical sub-beams traveling in a first direction, while having no overall effect on the polarization of optical sub-beams traveling in a second direction;
a third port for outputting one of the sub-beams of the input optical beam with the first polarization, and for inputting one of the sub-beams of the output optical beam with the first polarization;

a fourth port for outputting the other of the sub-beams of the input optical beam with the first polarization, and for inputting the other of the sub-beams of the output optical beam with the first polarization;

whereby light not having the first polarization entering the third and fourth ports will be spilled off without reaching the first or the second ports.